

# Estimates of Residence Time and Related Variations in Ground-Water Quality in the Puget Sound Lowlands

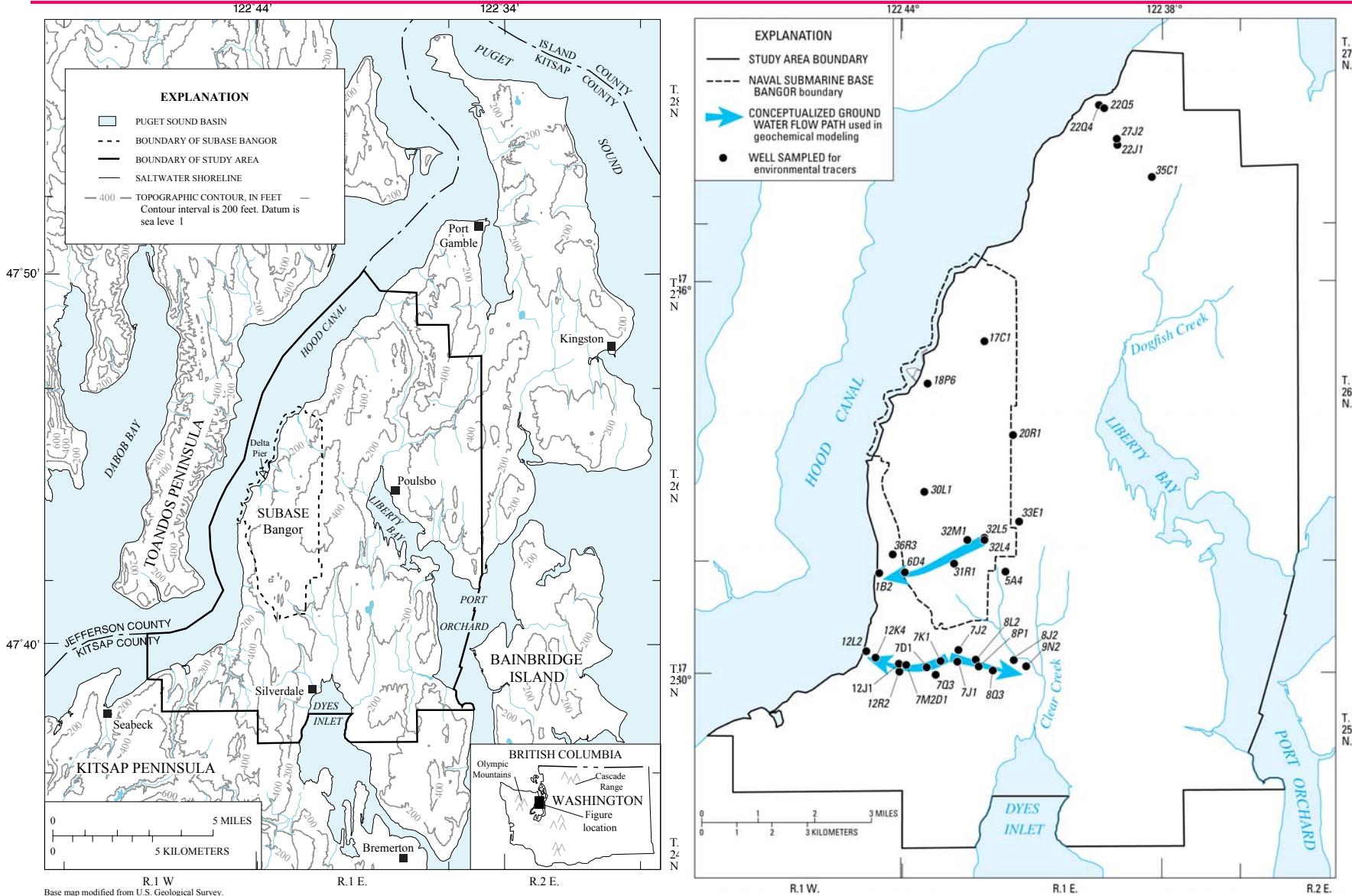
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Steve Cox and Rick Dinicola, USGS, Tacoma, WA

4<sup>th</sup> Washington State Hydrogeology  
Symposium: April 8, 2003



# Bangor study area & location of sampled wells

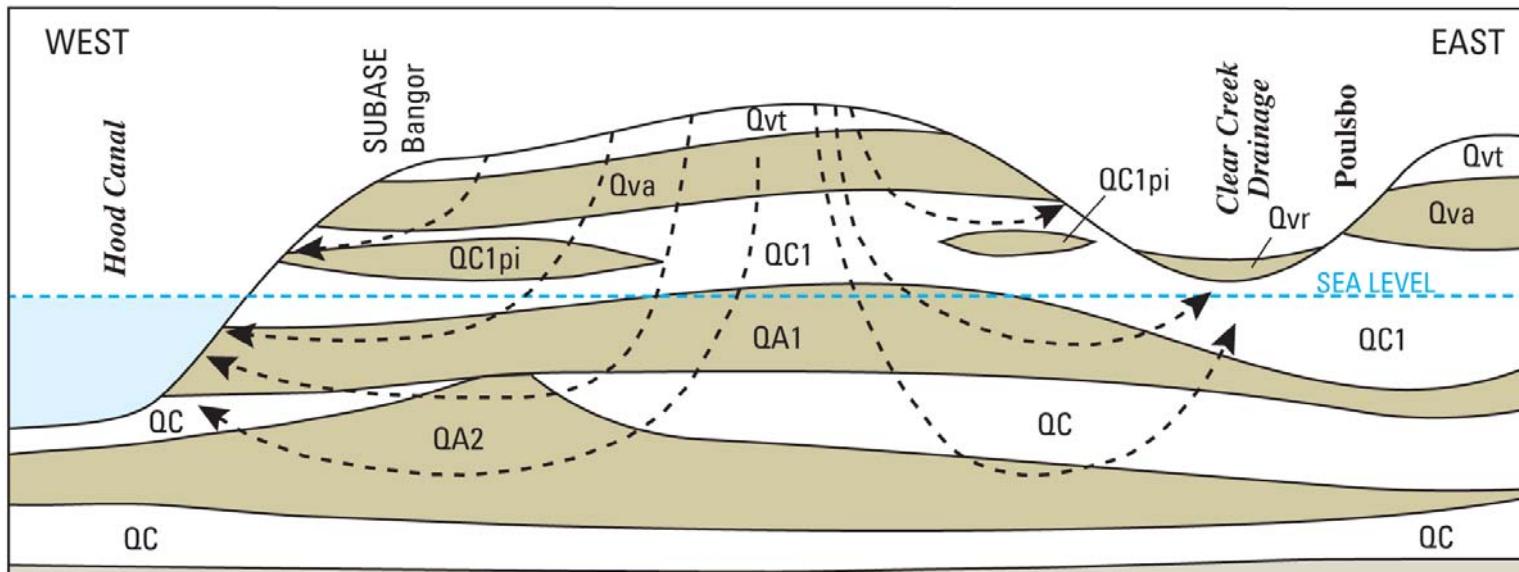


Base map modified from U.S. Geological Survey.

Scale 1:24,000 Digital Data

Projection: Universal Transverse Mercator, Zone 10 North American Datum 1927

# Schematic Hydrogeologic Section of Bangor Area



## EXPLANATION



### PERMEABLE UNITS

Qvr Shallow aquifer

Qva Vashon aquifer

QC1pi Permeable interbeds within  
the upper confining unit

QA1 Sea-level aquifer

QA2 Deep aquifer



### LESS PERMEABLE UNITS

Qvt Vashon till confining unit

QC1 Upper confining unit

QC Undifferentiated confining unit



Undifferentiated deposits



Bedrock



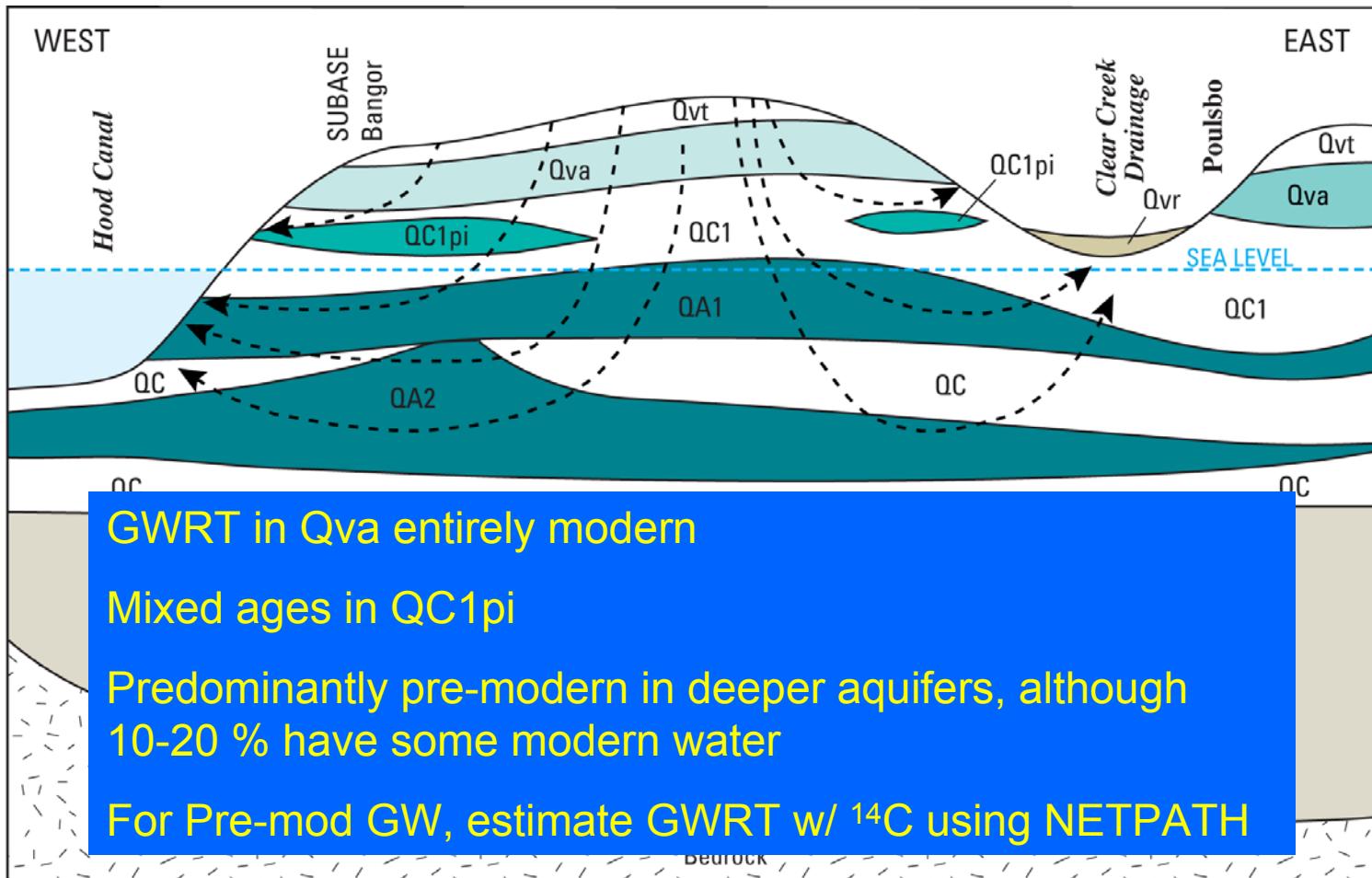
CONCEPTUALIZED GROUND WATER  
FLOW PATH

# Modern/Pre-Modern Classification of Ground Water based on concentration of environmental tracers

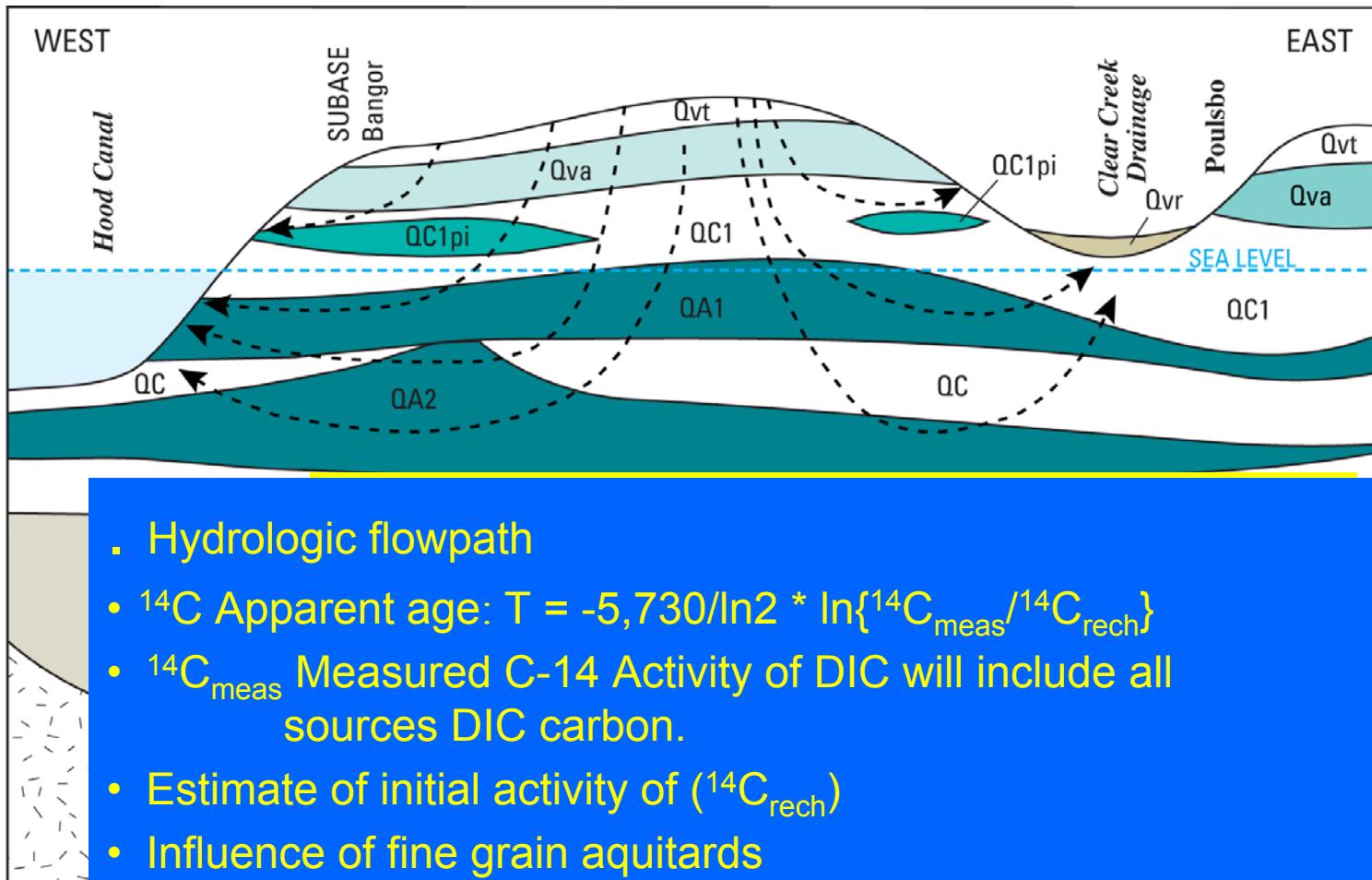
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	Pre-Modern	Indeterminate	Modern
Tritium (TU)	<.4	.4 - 1.	>1.
CFCs (pg/kg)	<20	21 - 25	> 25
$^{14}\text{C}$ (pmc)	< 85	85-100	>100

# General pattern of ground water residence times (GWRT) in hydrogeologic units near SUBASE Bangor

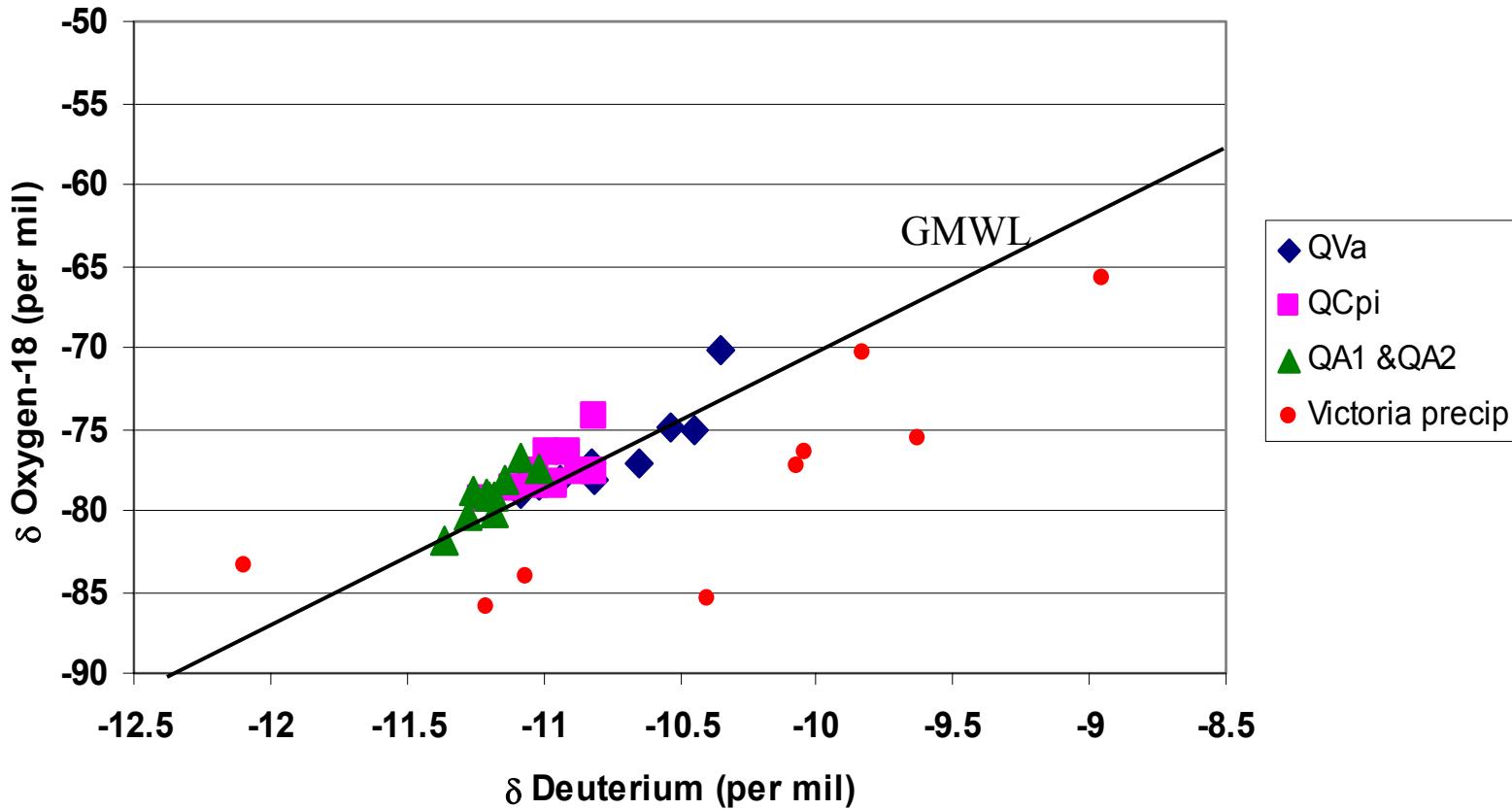


# Consideration in using the Carbon-14 approach to estimating GWRT

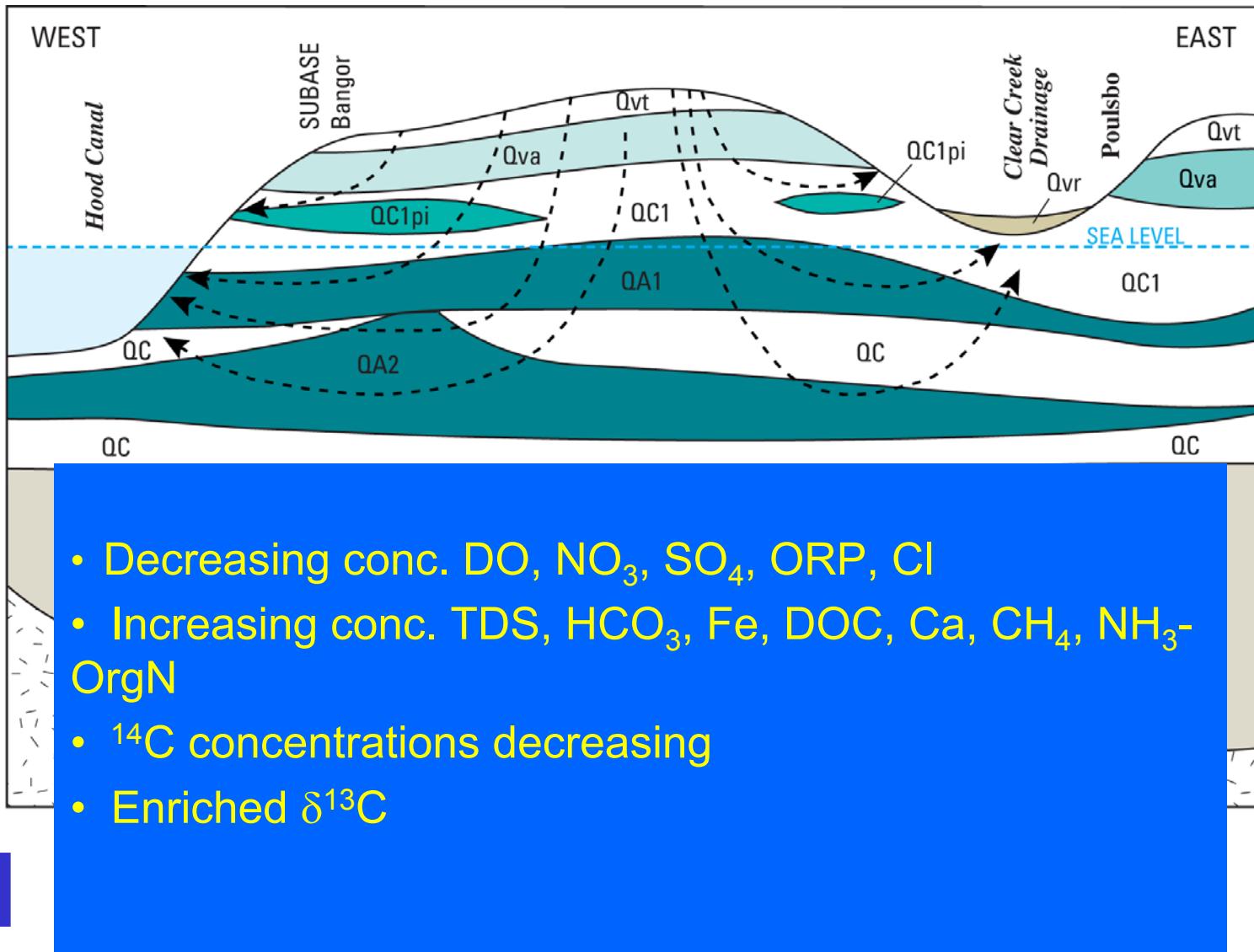


# Flowpath: Single source of ground water recharge

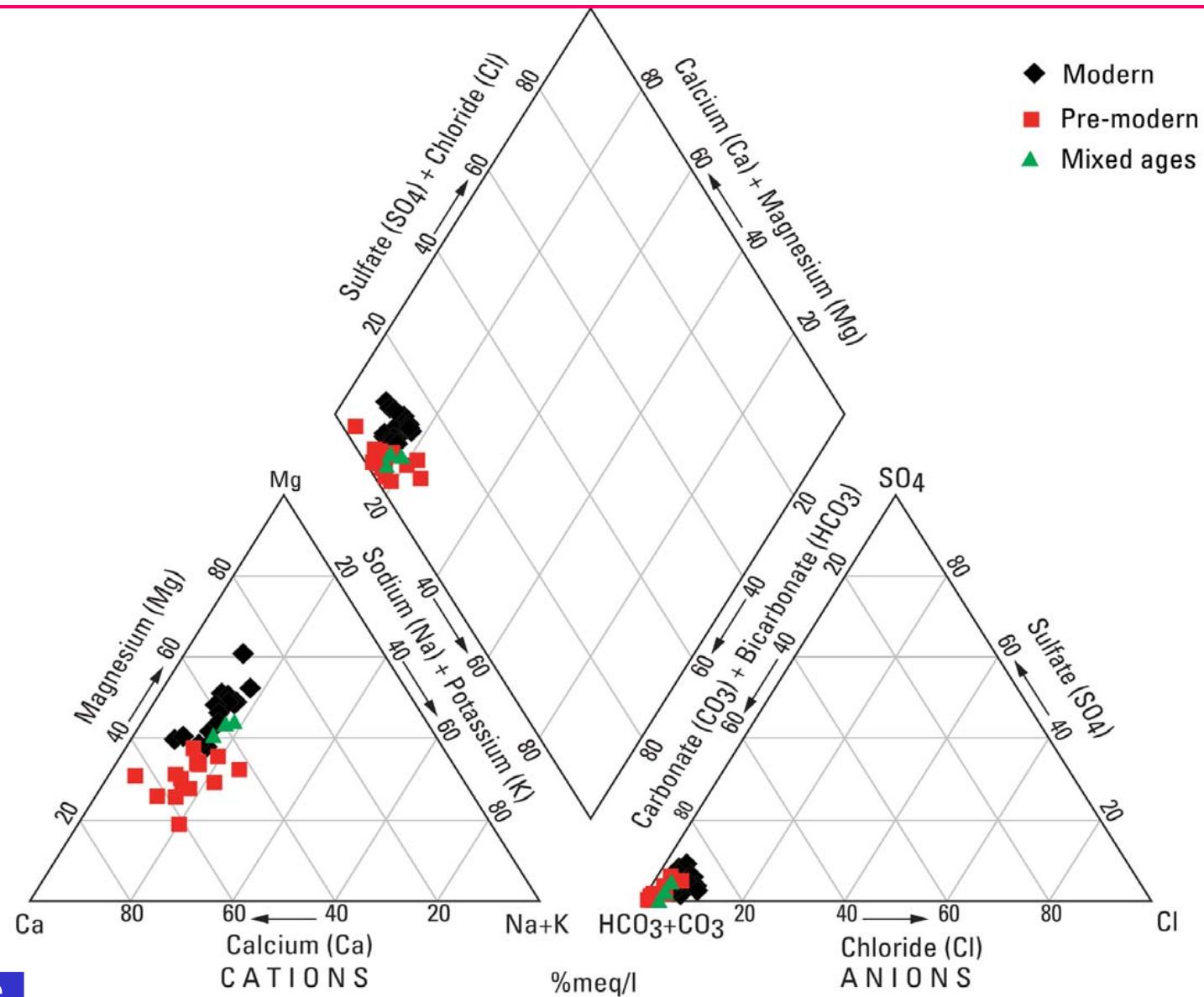
Stable Isotopes in Ground Water from the Bangor Area and in  
Precipitation from Victoria, BC



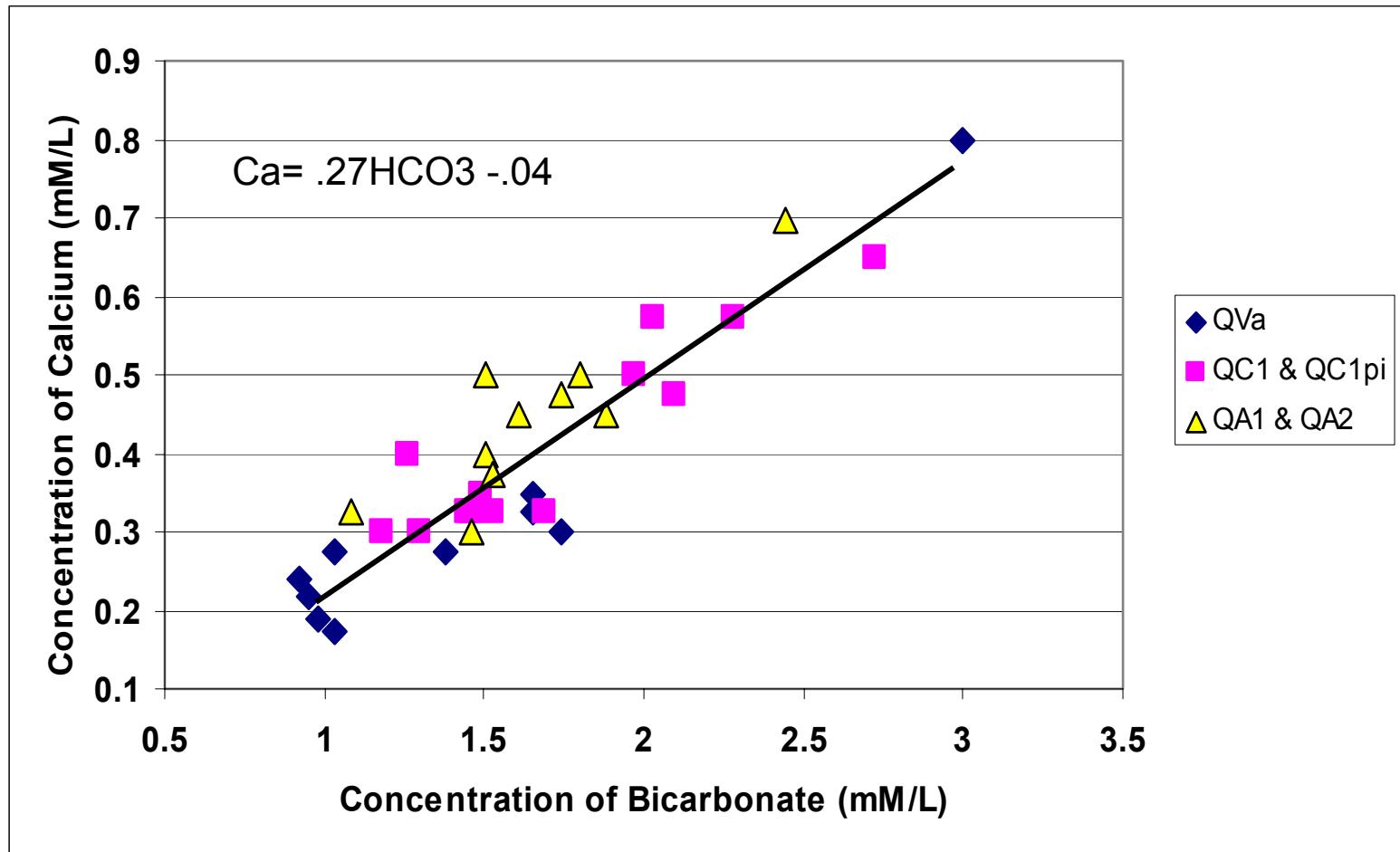
# Geochemical trends observed between GW recharge and discharge areas



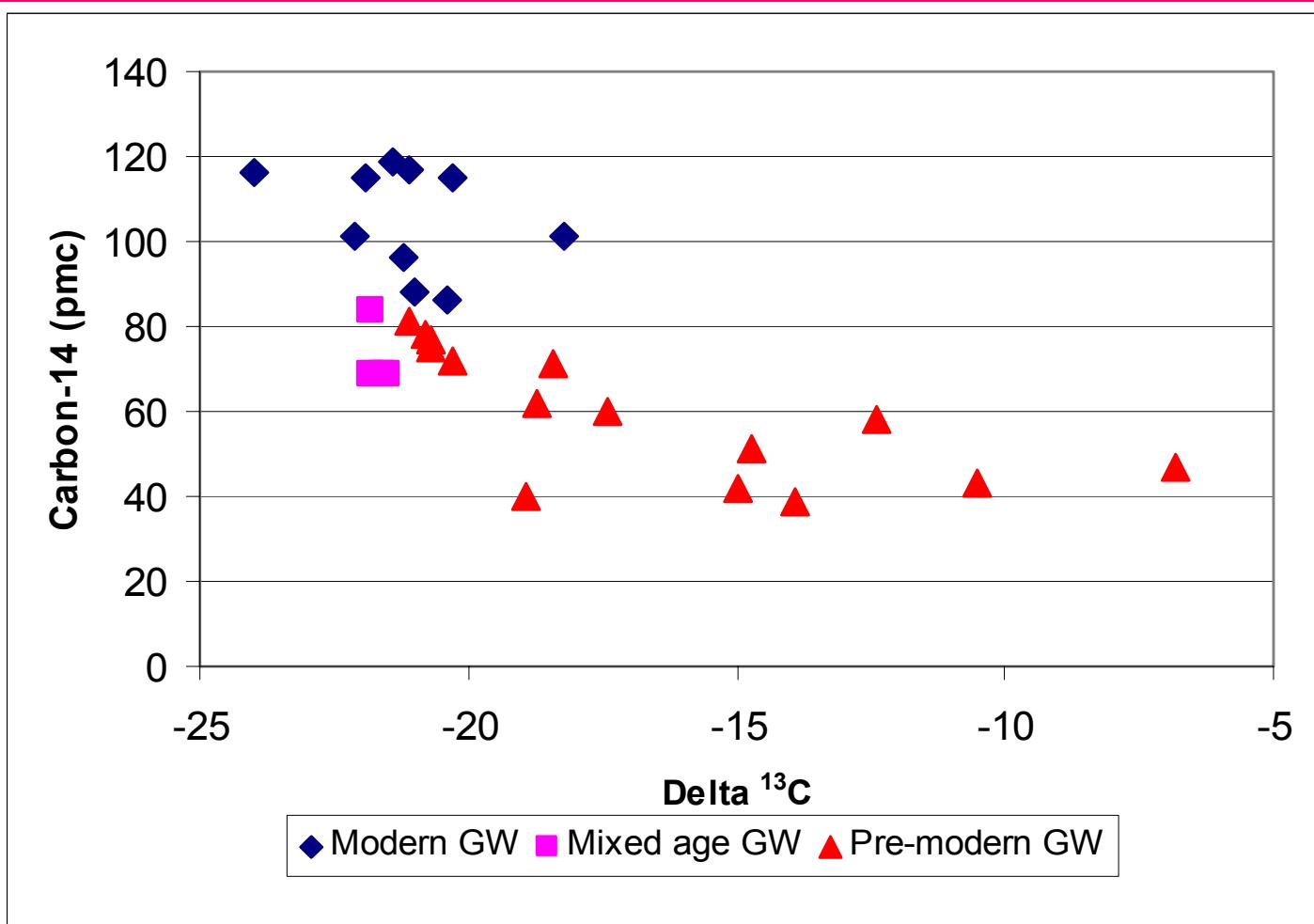
# Common ions in modern and pre-modern GW



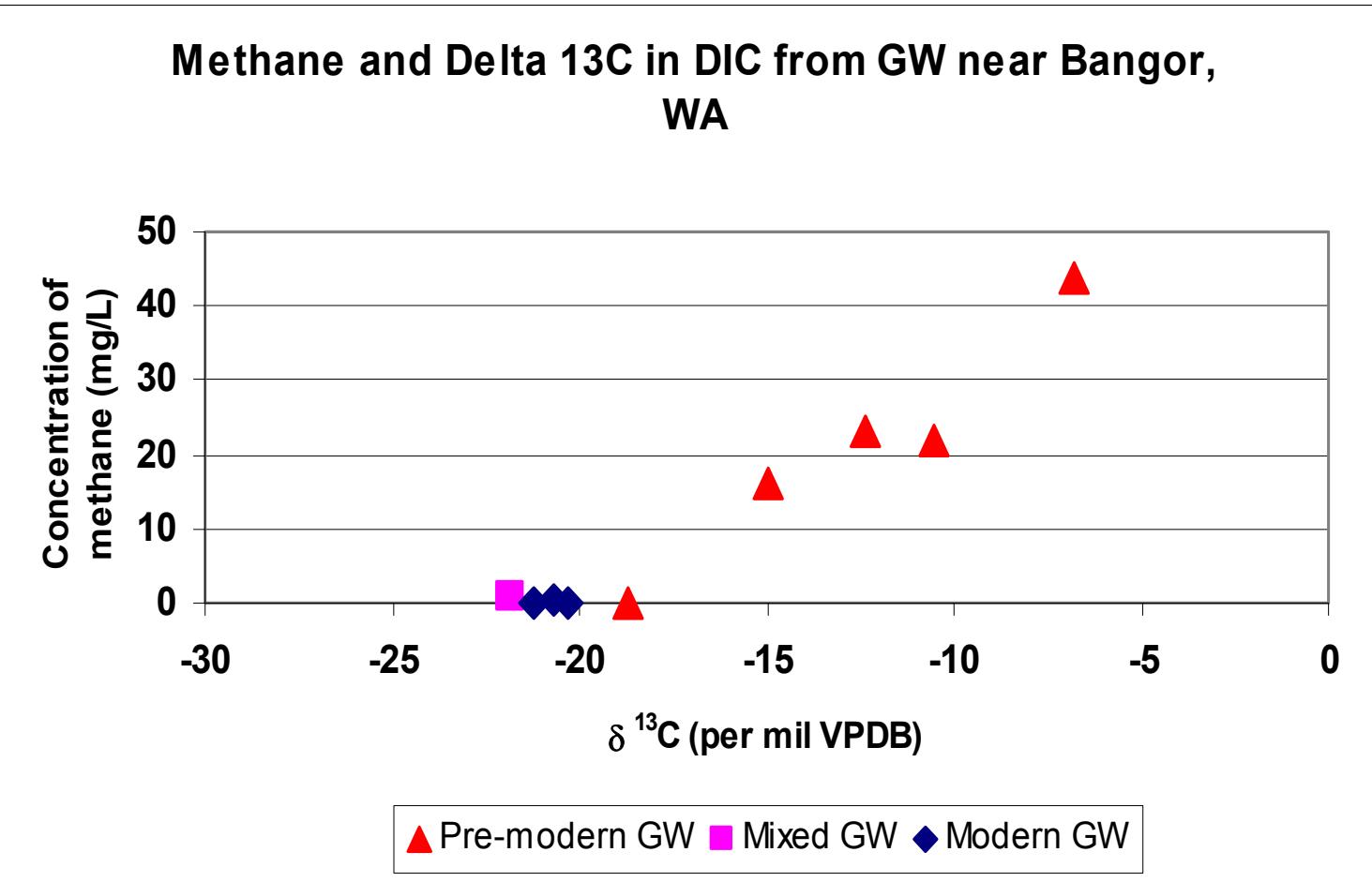
# Increasing GW concentrations of Carbon and Calcium



# Initial look at Carbon Isotopes Data



# Influence of Methanogenesis on Carbon-13



# Conceptual Model used in geochemical mass-balance modeling

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- Reactions: Oxidation of CH<sub>2</sub>O & methanogenesis, with silicate mineral diss & Ppt of geothite, smectite & pyrite
  - Phases included: Organic matter (CH<sub>2</sub>O), geothite,, CH<sub>4</sub><sub>g</sub>, pyrite, calcite, chlorite, augite, smectite, mafic-mont, Ca/Na exchange, and gypsum
  - Constraints: Redox, C, Ca, Na, Fe, S, Si
- 
- NETPATH --Inverse geochemical model
  - <sup>13</sup>C Isotopic data used to check model plausibility
  - WATEQF speciation code check of mineral SI

# Mass-transfers modeled by NETPATH

	Methanogenic				Non-Methanogenic		
	8j2	1b2	6d4	8q3	32I5	36r3	32I4
Phase/Unit	QC1pi	QA1	QA1	pi	QA1	QA1	QA2
CH2O	1.52	0.816	1.49	3.76	0.129	0.197	0.135
Ch4 gas	-0.663	-0.282	-0.213	(-2.75)	--	--	--
Pyrite	-0.012	-0.021	-0.21	-0.017	-0.009	-0.016	-0.006
Calcite	--	--	--	--		0.123	
Chlorite	0.88			2.24	0.032		0.047
Augite	0.958	0.819	0.327	2.45	0.462	0.199	0.351
smectite	-0.429	-0.434	--	-3.03	-0.255	-0.129	-0.208
Ca/Na exchange	0.019	0.063	0.074	0.226	0.022	0.009	0.009
geothite	-0.168	-0.059		-5.06	-0.129	0.02	-0.092
Mont-mafic	--	--	-1.29	--	--	--	--
so4, gyp	--	--	0.384	--	--	--	--

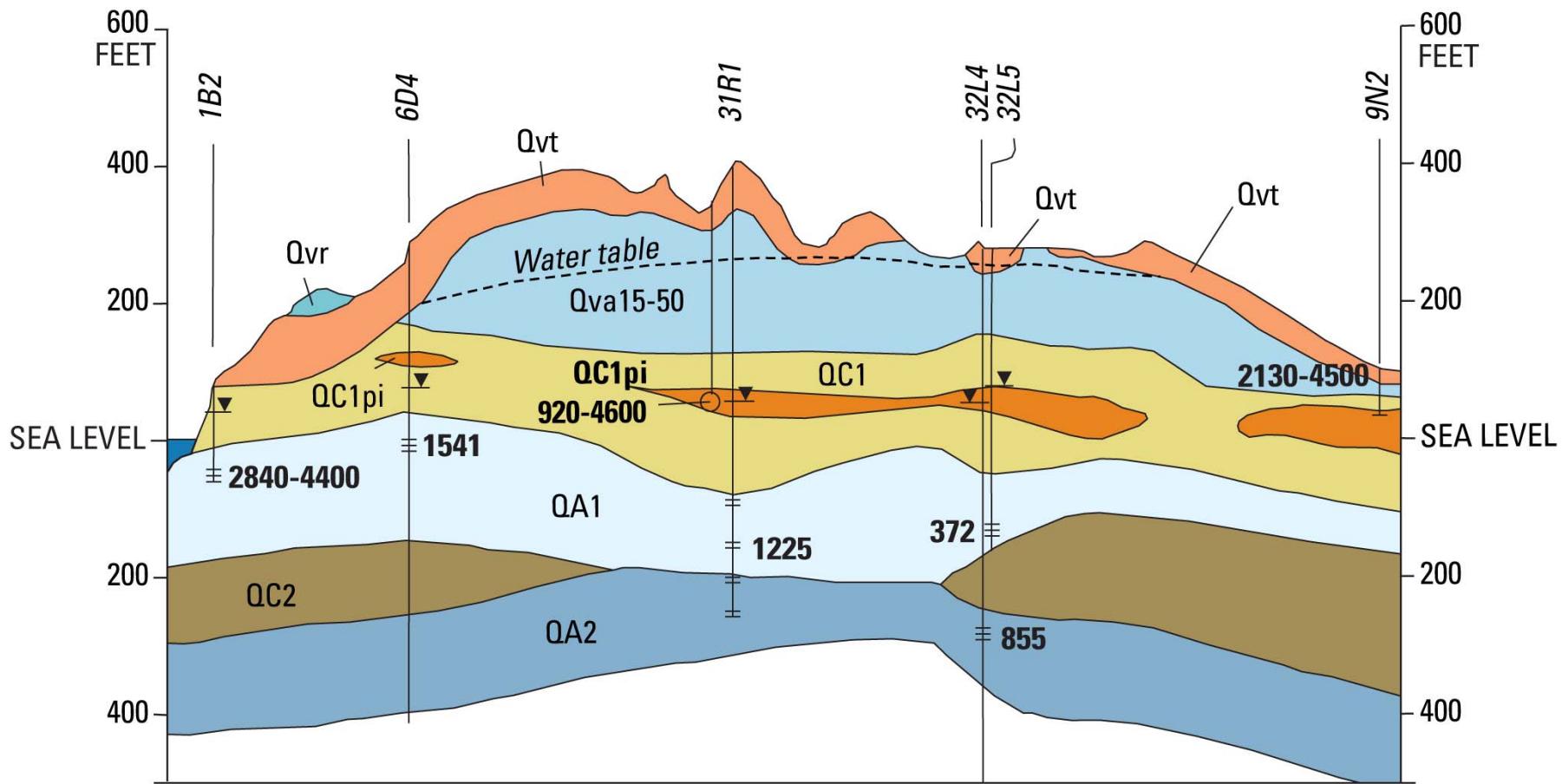
Comparison of C-13 observed in samples and C-13 calculated from mass-balance modelin

$\delta^{13}\text{C}$ ‰ observed	<b>-10.5</b>	<b>-13.8</b>	<b>-18.7</b>	-6.8	<b>-20.7</b>	<b>-20.7</b>	<b>-20.3</b>
$\delta^{13}\text{C}$ ‰ modeled	<b>-10.1</b>	<b>-15.2</b>	<b>-18.7</b>	-4.5	<b>-21.3</b>	<b>-19.8</b>	<b>-21.4</b>
C-13 Diff	0.4	1.4	0	2.3	0.6	0.9	1.1

# GWRTs generated from NETPATH modeling using a range of $^{14}\text{C}$ activities

	C14 aq. Org C	C14 Activity of Recharge Area		
		92pmc	85pmc	80pmc
9N2	15 pmc	4500	4000	3600
QC1pi	10 pmc	4000	3500	3000
	2 pmc	3200	2600	2100
	15 pmc	4400	4000	3500
QA1	10 pmc	4300	3700	3200
	2 pmc	3900	3300	2800
	15 pmc	1500	870	370
32L4	10 pmc	1500	860	350
	2 pmc	1400	780	250
	15 pmc	-980	-1600	-2000
QA2	10 pmc	-1200	-1800	-2300
	2 pmc	-1500	-2100	-2600
	15 pmc	-	-	-
22Q4	15 pmc	-	-	-
QC1pi	10 pmc	-	-	-
	2 pmc	-	-	-

# Distribution of model ground water ages in schematic section of Bangor area



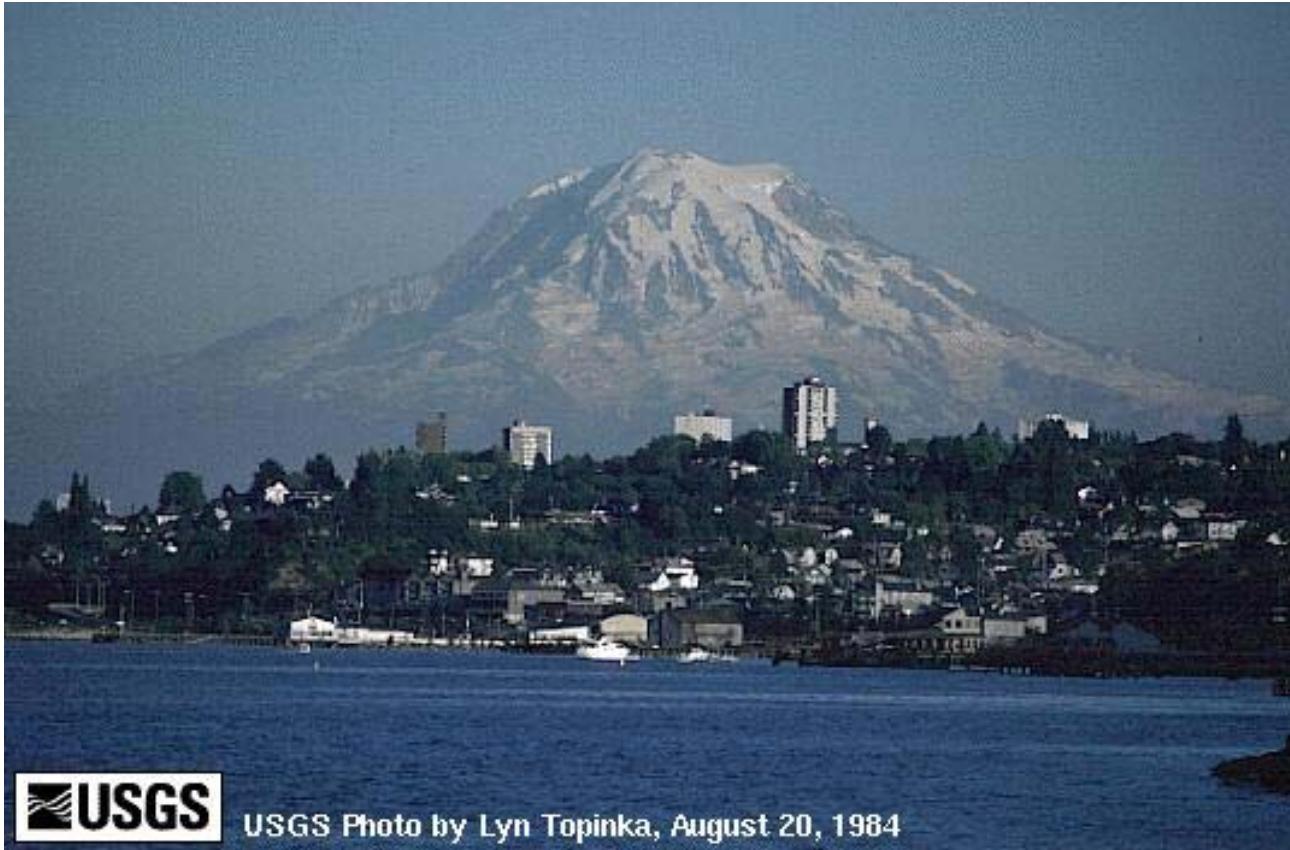
# Summary

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- GWRT: Qva-mod, QC1pi-mixed, QA1 Pre-mod
- 10-20 % of deeper GW mixed (>depleted  $\delta$ )
- Large increase in carbon along flow path, although largest conc not always near end of flow path
- DOC \*\*\*Methanogenesis occurs were OC is sufficient and influences  $^{14}\text{C}$  estimates of GWRT
- $^{14}\text{C}$  estimates of GWRT <4600 yrs
- Apparent ages typically twice model age
- Model ages larger than particle-track ages

Bangor age-dating report available soon on line  
[at://water.usgs.gov/pubs/wri/wri034058/](http://water.usgs.gov/pubs/wri/wri034058/)

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USGS Photo by Lyn Topinka, August 20, 1984

**USGS Water Science Center in Washington:**  
<http://wa.water.usgs.gov>